

## **Airships and Conventional Air Transportation Systems. Insights and Challenges for Portugal.**

Lia Pereira<sup>1</sup> and Jorge Silva  
Aerospace Sciences Department  
University of Beira Interior  
Covilhã, Portugal

**Abstract:** Technological developments and environmental concerns are among several reasons that are bringing up once again the concept of new air transportation vehicles like the airships. Nowadays airships have several applications such as: heavy cargo and point-to-point transportation, advertising, observation, patrolling and monitoring, research, and tourism. This work examines the technological improvements in this particular sector of aviation and shows the feasibility of airships in certain market niches.

**Key-words:** Airships, Cargo and Passenger Air Transportation, Market Niches

### **1. Introduction**

The beginning of the century brought the revival of an interest on airships and their applicability in such diverse fields as the military and commercial ones. This interest is inspired by advances in several technological areas and mainly it concerns the specificity of these aircrafts that make them able to complement the traditional air services, for example on patrolling and monitoring of airspaces and borders - which requires a great autonomy, on the transportation of heavy and bulky cargo - where the use of airships is far more viable especially for short distances, and on missions of vertical compact cargo lift - economically more sustainable than those usually made using helicopters.

Climate changes and the progressively rising of fuel costs helped these aircrafts to become attractive both economically and environmentally, and mainly for these reasons the

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<sup>1</sup> Corresponding Author: Tel: +351 275 329 732; Fax: +351 275 329 768; Email: [lia\\_pereira\\_83@hotmail.com](mailto:lia_pereira_83@hotmail.com)

encouragement of innovation has been gradually supported not only by private investors but also by some governments also with concerns about rethinking their transportation systems. The rebirth of this mean of transportation, capable to overcoming easily some deficiencies of the conventional ones, brings in medium/long term economic benefits offering different services at lower costs and may stimulate new commercial and industrial activities and even new transactional routes.

Considering the relevance of the use of airships within the context of a sustainable project this work also underlines the sense for Portugal to carry out a study aimed at examining not only its technical and economic feasibility but also its acceptance by the customers in general.

The work is structured as follows: a state of the art supporting technically the feasibility of the use of airships; a description of both the operational applicability and limitations of those aircrafts; a survey conducted within Portugal to evaluate the acceptance of airships; and finally some conclusions about future research on this specific field.

## **2. State of the Art**

The state of art of airship presents new research that paves the way for the resurgence of renewed horizons for the application of airships, including new technologies of production far away from the archaic ones used by mid Twentieth century.

As the envelope constitutes the main structural element in airships it requires particular care since the design phase up the limit of the operational lifetime of the aircraft. It is crucial to design an envelope which is to be pressurized and to endure, both in flight and on the ground, and to support the highest values of loading allowing this way to determine the efforts that limit the strength of the fabric of the envelope itself. It is necessary to pay attention to the technology of the fabric too to accomplish with the requirements for airworthiness.

For safety reasons it is mandatory to submit the materials that make up the envelope to fatigue analysis. These materials must accomplish with the following characteristics:

- High Strength: the strength of the material determines the maximum size of the envelope;
- High Strength/Weight Ratio: to minimize the weight of the envelope;
- Environmental Degradation Resistance: factors such as temperature, humidity and ultraviolet light are crucial to the life of the envelope and the maintenance costs;

- High Resistance to Shock/Hack: to provide better tolerance against damage;
- Low Permeability: to minimize the loss of helium - which increases both operational costs and operational capability losses.

The study of the tissue should include analysis of tears and its propagation in the manufacture process of the envelope. A common method is the so called *Cut Slit Test Method* [1]. The resistance of the material used in the envelope is dependent on its manufacture process. There is already a significant database for the different types of material that can be used, allowing access during the design phase for a related wide choice which constitutes a very useful tool for designers. The choice of material must also take into account the likelihood of structural failure concerning the instability of the material subjected to vibration. Laminated materials [2] are the most used in the manufacture of the envelope but recent research advancements suggest the emergence of more resistant fibers and with low density: Polyester (Terylene, Dacron), Polyamides (Nylon) and Aramids (Kevlar 49, Kevlar 29). The main advantage of these materials is that they may adopt different characteristics just by the choice of their base components thus supporting forces applied to the structure of the envelope, retaining the gas in the envelope, and guaranteeing resistance to environmental and meteorological factors. It is necessary to ensure that lifting gas is safely retained in the envelope; for this special purpose nowadays is used the Polyester Film (Mylar - Du Pont) due to its characteristics of low permeability and high rigidity. Also some materials used for the retention of gas are excellent for the layer of protection against environmental and climatic factors such as Polyvinyl Fluoride Film (PVF) or Tedlar - Du Pont, mainly for being virtually inert at ambience temperature to several acids, alkalis and solvents, and for showing greater resistance to actinic degradation, if compared with other synthetic materials.

Since the beginning of this century several research works deeply studied the viability of the application of renewable energy systems to airships as electrical propulsion and energy storage, photovoltaic systems, and removing systems of residual heat. In 2001 NASA's Glenn Research Center (NASA/TM - 2005-213427) [3] conducted a research for the employment of such propulsive systems to airships involved in long-duration missions. In a project of this magnitude it is imperative to consider the energy system for the propulsive and aerodynamic performance of the aircraft, as a whole, to ensure the minimum weight of the set and the proper balance between the generation, storage and consumption of solar energy, necessary to propel the airship taking into account seasonal variations of wind and sunlight, objectives of the mission, and latitude and altitude of the flight. All these factors represent conceptual

challenges because the area used for the PV panels is directly affected by the size of the aircraft. Changing the size of the aircraft not only the amount of solar energy generated is different but also the amount of energy required to overcome drag propulsion system will vary. For airships with renewable energy propulsion it is necessary to invest in more deeply research concerning regenerative technologies, more efficient and lighter than energy generation systems, fuel cells and photovoltaic panels.

Airships use its own gas in the take-off and soaring phases, and engines, stabilizers and rudders to move in the air and control the flight. Nowadays these aircrafts use fly-by-light controls thus they are highly versatile. During take-off and landing phases they may operate in the following ways [4]: CTOL (Commercial Take-Off and Landing), VTOL (Vertical Take-Off and Landing), and STOL (Short Take-Off and Landing). Also modern airships have air navigation instruments for IFR (Instrument Flying Rules) purposes in parallel with night vision systems (Infrared), weather radar to enable night operations, and GPS (Ground Positioning System) applications to provide location data (latitude and longitude) by geostationary satellites.

### **3. Applicability**

Thinking about the future the rebirth of airships promises to solve the differences between means of transportation quicker but expensive and highly polluting as planes and helicopters, and means of transportation slower less expensive but also very pollutants as ships and trucks. Considering these limitations of common systems and driven by the technological improvements in the aviation industry which contribute to the construction of safely airships with capacity and expertise to revolutionize the transportation paradigm, one is led to understand the contribution of these vehicles to complement the traditional air cargo and passengers transportation systems.

Considering the actual panorama of the transportation networks the use of airships for commercial and civilian purposes is at least revolutionary: perishable goods can be transported over longer distances, heavy or manufactured goods can be carried directly from the source to the destination without the need of any other transportation mode, and transportation of dangerous goods can be accomplished avoiding populated areas.

The wide set and variety of potential areas for application of airships press down the investment risk mainly because the particular fields where its applicability prove to be unhelpful is compensated by others in which their use exceeds the initial expectations.

This work intends to survey the most relevant tasks for future applicability of airships in anywhere, including Portugal, taking into account the most relevant developments in the world as, for example:

- **Surveillance and Monitoring:** due to its characteristics of long operational autonomy the airships can accomplish with long-duration missions, that is, for long periods of time without refueling, serving as platforms for communication, surveillance and monitoring;
- **Rescue, Emergency and Fire Fighting:** due to its large autonomy and capacity the airships can be used as platforms to transport brigades, material and equipment to any incidents/accidents areas, for rescue and emergency operations, and into firefight scenarios; due not only to its offshore extension but also to its extensive forest resources, Portugal is an excellent candidate for the use of airship in such missions;
- **General, Heavy, Perishable and Indivisible Cargos:** cargo value is dependent on the type of goods but on its characteristics in the destination too, so that the choice of the transportation mean derives from the relationship between time, postage to pay, accommodation quality and temperature control (whenever necessary); Table I highlights some operational and performance characteristics of airships facing some conventional modes of transportation which may be determinant in a decision process;

OPERATIONAL CHARACTERISTICS	AIRSHIP VS MARITIME	AIRSHIP VS HIGHWAY	AIRSHIP VS RAILWAY	AIRSHIP VS AERIAL
Speed	Much Faster	Faster	Much Faster	Much Slower
Load Capacity	Less Capacity	Much more Capacity	Less Capacity	Increased Capacity
Load Adaptability	Much more Flexible	Less Flexible	Much more Flexible	More Flexible
Transportation Costs	Much more Expensive	More Expensive	Much more Expensive	Much more Economic

Table I. Key Operational Characteristics of Airships for the Transportation of Goods (Adapted from [5, 6])

compared with some conventional modes of transportation airships have specific characteristics that allows to predict its applicability into several market niches; effectively if compared with the usual air transport system airships have a higher aptitude for long-duration missions without refueling and so they are more economic

because their operating and maintenance costs are lower; in the next future it will be possible to balance between the use of airships as a complement between fast but more expensive air transportation and more economic but slower sea and rail transportation; nowadays the technology already used in airships enables them to reach speeds around 128.75 km/h, that is, 3 to 5 times higher than shipping; so the rebirth of airships is an auspicious event balancing between operating rates higher than for shipping and taxes lower than for conventional air transportation; in Portugal airships may operate in complementary missions with helicopters since they have greater both freight lifting capacity and autonomy for example for the transportation and installation of towers for electrical power and for wind turbines - and several and heavy related equipment too, without requiring the construction of specific support infrastructures;

- **Passengers:** nowadays the main target of passenger transportation by airships is related with the Tourism sector, that is, for those to whom a quite aerial tour is the best way to appreciate nature; nevertheless one expects that in the next future the use of airships will reach the business sector too where a comfortable flight has the advantage to bring customers directly from an origin to a destination in the center of the town, for example, without the necessity of any other complementary transportation modes thus allowing businessmen to save time and money.

These are some of the reasons why airships emerge as a serious and viable alternative to the conventional transportation systems. However one assumes that before inserting the airships in any transport network it is necessary a better understanding on its safety patterns, durability, and attractiveness of the cost/time relationship face to the conventional alternatives. But this is an effort to be done gradually.

#### **4. Limitations**

More than 20% of aircraft incidents/accidents with conventional aircrafts are driven by climatic agents such as thunderstorms, hail, sudden turbulence and ice, among several others. Then it can be said that concerns about environmental factors and weather conditions are not exclusively of airships operations as even the more sophisticated aircrafts are affected and they need more and better technology to predict and avoid the related flight risks too.

For the airships operations the influence of meteorological factors is evident and leads to more concerns than for the transportation operations by sea, road and rail, even if the

precautions against the weather conditions are similar (Table II); but as previously mentioned modern airships have onboard specific equipments which enable safety flights under the requirements established by ICAO (International Civil Aviation Organization).

<b>CLIMATIC FACTORS</b>	<b>MARITIME</b>	<b>HIGHWAY</b>	<b>RAILWAY</b>	<b>AERIAL</b>	<b>AIRSHIP</b>
Thunderstorm	Little Affected	Little Affected	Affected	Affected	Affected
Heavy Rain	Little Affected	Affected	Little Affected	Affected	Affected
Strong Wind	Affected	Little Affected	Little Affected	Affected	Much Affected
Storm	Much Affected	Much Affected	Affected	Much Affected	Much Affected
Ice	Affected	Much Affected	Little Affected	Much Affected	Much Affected
Hail	Little Affected	Affected	Little Affected	Affected	Affected

Table II. Environmental Factors Affecting Modes of Transportation [Authors]

Another vulnerability of the airship may be the difficult to maneuver close to the ground because of some eventual instability; however recent technological advances such as the control fly-by-light propulsion vectorize over 90 and flight ability hover-skirt contribute to overcome this problem.

The rebirth of the airships exposes the lack of legislation existing in several countries to accommodate the operation of such vehicles and thus the need for the authorities to determine the operational standards to ensure safe airworthy patterns. As there is legislation to ensure safety requirements of conventional aircrafts, commercial or non-commercial ones, it is imperative to establish a parallel with the airships; mainly for safety purposes but also to reassure its potential market. Portuguese Civil Aviation Authority (INAC – Instituto Nacional de Aviação Civil) published a Technical Information (No. 09-02 - Issue 1) in practice a transcription of PART M of EC Regulation No. 2042/2003. It is an official statement related to airships although for non commercial use.

**5. The Case for Portugal**

5.1. The Aeros 40D Sky Dragon and SkyCat-20/220 FireCats

After the introduction of some facts underpinning the operational feasibility of the airships, its advantages and limitations, and the importance of a regulatory framework for its airworthy use within safety patterns, it is necessary to study its eventual applicability in Portugal. The

entrepreneurship is always needed in such an innovative project in order to cut with wrong ideas about airships as unsafe aerial vehicles.

The Aeros 40D Sky Dragon project (Figure 1) is a good example of an aircraft lighter than air already certified in the USA by the FAA (Federal Aviation Administration), in Germany by the Luftfahrt-Bundesamt (LBA), and in China by the General Administration of Civil Aviation (CAAC).



Figure 1. Project Aeros 40D Sky Dragon [7]

Due to the technology associated with the construction of its envelope this airship is invisible to radar, and the peculiarity of the use of a configuration in blade converts it into a very silent aircraft; therefore the Aeros 40D is an excellent platform for surveillance missions including monitoring of forests and controlling of traffic.

Portugal is the country of the European Union with the largest exclusive economic maritime area, a portion of the Atlantic sea up to 200 nautical miles from the coast and equivalent to an area 63 times that of the mainland.

<b>MILITARY AND STATE USE</b>	<b>CIVIL AND COMERCIAL USE</b>
Control platforms	Aerial photography and broadcasting events
Location of specific targets	Hydrogeological forest monitoring,
Navigational support	Topography purposes
Disaster areas monitoring	Observation of wildlife and exploitation of environmental resources
Traffic monitoring	Urban planning monitoring
Pollution monitoring	Tourism

Table III. Airships Applications for Military/State and Civil/Commercial Use (Adapted from [5, 6])



The Aeros 40D is a very versatile airship, has a good economic and operational performance, and has a low cost production and maintenance, concurrently with its capability to perform missions of long durability when compared with the traditional air transportation system. Table III points some of its possible applications in Portugal.

Projects such as SkyCat-20/220 FireCats (Figure 2) are examples with a potential market in Portugal too because of the forest area of the country which covers 35.8% of the territory.



Figure 2. Projects SkyCat-20/220 FireCats [8]

Every year the Portuguese forests are plagued by the fire causing enormous losses both of timber and of money. In 2003 the burnt area was of 425.726 hectares, the highest of the last 29 years. In monetary terms this loss meant 50 million of euro.

The aerial surveillance of forests is carried out mainly by small airplanes and helicopters supported ashore by a net of airfields. The main disadvantages are those related with the difficulty to monitor the forest areas and the autonomy of airplanes and helicopters thus increasing the operational costs. The above mentioned airships are able to carry from 20 tons (SkyCat-20) to 220 tons of water (SkyCat-220) more than the capacity (90 tons) of the Evergreen Boeing which is the largest firefighting airplane in the world.

Apart from its undoubted capacity the airship is a versatile aircraft, able to cover large areas without significant operational limitations, with low operating costs per area covered, and when equipped with sensors which combine the capture of real images with infrared spectrum still has the capacity for surveillance missions at night, of scalable monitoring, and of detection of the location of outbreaks of fire.

## 5.2. The Survey

An online survey was conducted in April 2010 [9] to test the acceptability of an airship within an universe of portuguese potential users. It was divided in several parts: to identify the respondent characteristics, to know what kind of knowledge the respondents had about airship and its confidence on them, to identify some issues concerning the use of aircrafts for tourism purposes, and to find out the impact in the population of more information about these vehicles.

For a population of around 500 respondents 43% are aged between 18 and 29 years (Figure 3), 70% are male (70%) (Figure 4), 75% have a higher education level (Figure 5), and 61% are employed (Figure 6).

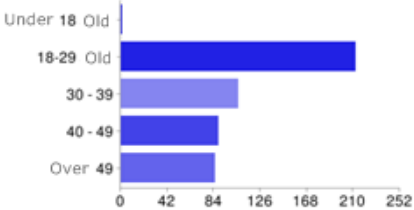


Figure 3. Age

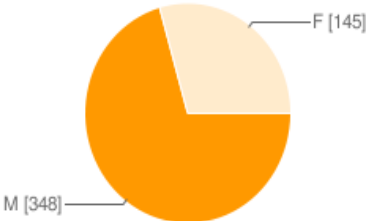


Figure 4. Sex

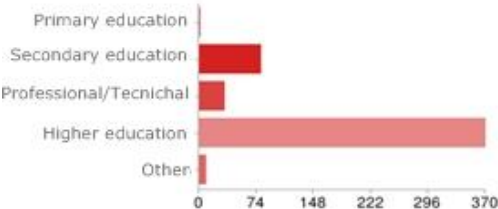


Figure 5. Level of education

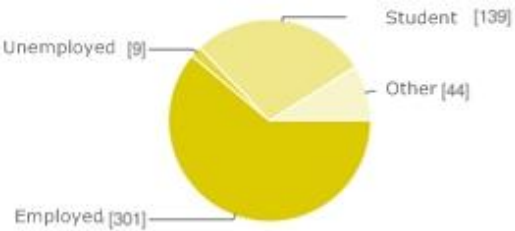


Figure 6. Occupation

Accordingly with the questions:

- “Do you know what is an Airship?”, on a scale from 1 (totally unaware) to 5 (knows perfectly), 47% answer “perfect knowledge” (Figure 7);
- “Would you make a voyage on an Airship?”, on a scale from 1 (never) to 5 (of certainty would travel), 40% answer “with certainty”(Figure 8);
- “Would you use an airship to carry goods?”, on a scale from 1 (never) to 5 (with certitude), 32% answer “with certainty” (Figure 9);

- “Would you consider the Airship as an air transportation mode (...)”, on a scale from 1 (not effective) to 5 (highly effective), 45% consider the airship “effective” (Figure 10);
- “How do you classify the flight safety of the Airship?”, on a scale from 1 (very safe) to 5 (extremely safe), 40% consider the airship “safe” (Figure 11);

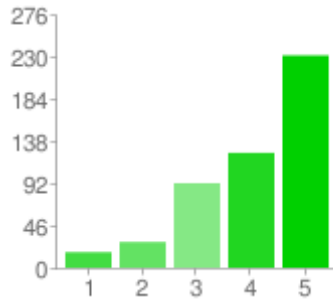


Figure 7. Airship knowledge

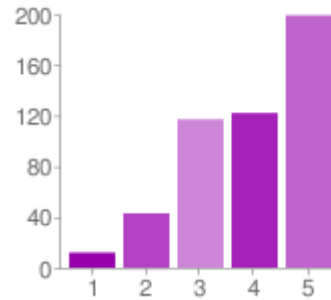


Figure 8. Respondents that would travel in an airship

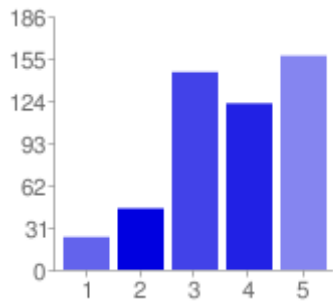


Figure 9. Respondents that would transport goods in an airship

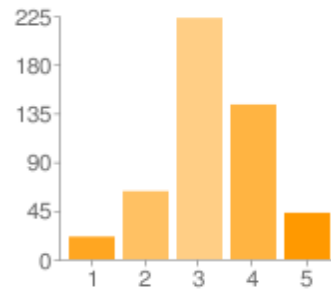


Figure 10. Airship rating as to its effectiveness

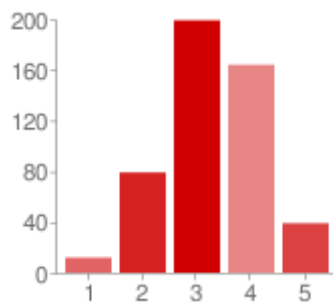


Figure 11. Airship rating as to its safety

- “Among the following tourism tours which of them would you like to do in an Airship: Route of Vale do Ave, Route of Minho, Route of Douro, Route of Beiras, Route of Lisboa e Vale do Tejo, Route of Alentejo, Route of Algarve, Other?”, 47% chose “Route of Douro” (Figure 12);

- “Among the following tourism tours which of them would you like to do in an Airship: Route of Madeira, Route of Azores, Other?”, 59% chose “Route of Azores” (Figure 13);
- “What kind of services do you think that an Airship could provide: Tourism/Cruise, Patrol/Surveillance, Environmental Monitoring, Event Coverage, Advertising, Fire Fighting, Heavy Cargo Transportation, Particular Transportation, Other?”, 85% admit that an Airship is able to provide services like “Tourism/Cruise” (Figure 14);
- “How much would you be willing to pay for a tourism tour of 30 minutes in an Airship: Less than 50€, 50€ - 100€, 100€ - 200€, More than 200€?”, 64% would pay “less than 50€” (Figure 15);

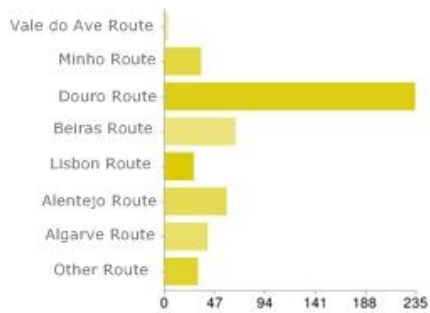


Figure 12. Preferences of tourism tours in Portugal (Mainland) to be done by airship

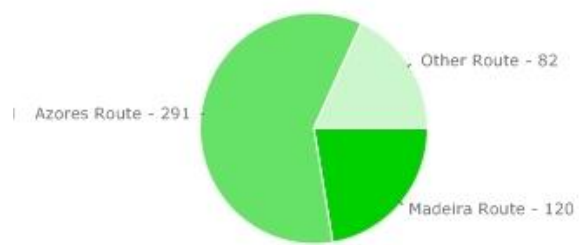


Figure 13. Preferences of tourism tours in Portugal (Islands) to be done by airship

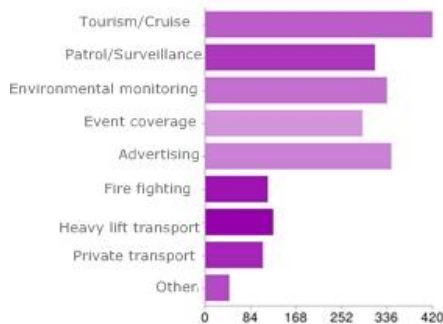


Figure 14. Services to be done by airship

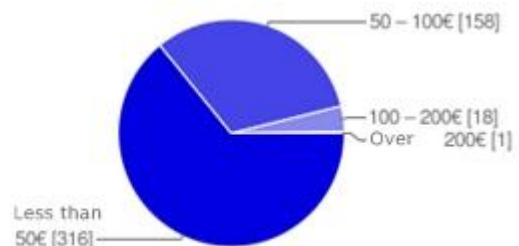


Figure 15. Prices for airship tourism tour

- “Information about airships is (...)”, on a scale from 1 (unsatisfactory) to 5 (highly satisfactory), 38% answer “unsatisfactory” (Figure 16);

- “The best way to disseminate more information about airships would be: General Newspapers/Magazines, Specialized Newspapers/Magazines, TV, Radio, World Wide Web, Email, Other”, 87% answer “TV” (Figure 17);
- “Access to more information about airships would be (...)”, on a scale from 1 (not relevant to change my opinion) to 5 (very relevant to change my opinion), 31% answer “significant” (Figure 18).

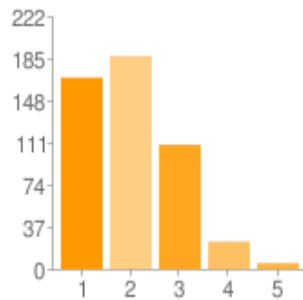


Figure 16. Satisfaction concerning the information about airships

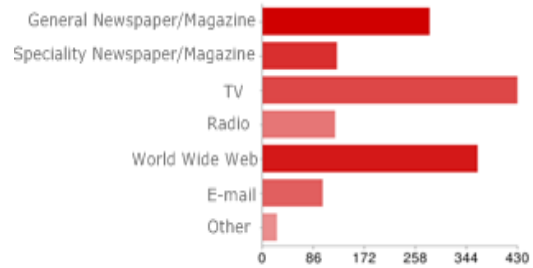


Figure 17. Best means of dissemination of information about airships

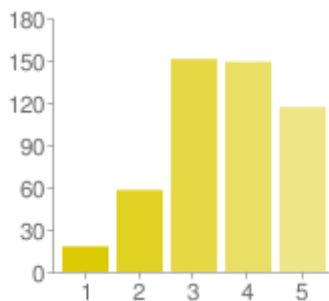


Figure 18. Relevance of access to more information to change the opinion of respondents about airships

## 6. Conclusions

The State of the Art on modern airships allows the construction, maintenance and operation of such aircrafts with high load capacity and accordingly with safety standards.

Overcame an initial phase of mistrust one believes that airships will impose economically and strategically in regional and national transportation systems.

In Portugal there is a growing interest in this aircraft and already there is a first intent of a conceptual design which is a promise signal.

A preliminary online survey surpasses the initial expectations and gives very positive statements about the acceptability of an airship even if taking into account some operational limitations.

One believes that a more deep economic and strategic study will help to dispel doubts that may still exist about the feasibility of this project in Portugal.

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